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ROOM TEMPERATURE STUDIES OF CR DOPED COPPER OXIDE THIN FILMS BY REACTIVE DC MAGNETRON SPUTTERING

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ABSTRACT

Cr doped and undoped CuO thin films deposited on glass substrate at room temperature by reactive dc magnetron sputtering. The Pure CuO is doped with 2W sputter power of the Cr concentration. The XRD results shows that the structure of the compound was conformed as monoclinic in (0 0 2) orientation. The Surface Morphology study reveals that the atoms are arranged in uniform fashion and EDAX data conforms that the compound has the dopant Cr in addition to the Cu and O. The optical energy band gaps can be calculated from UV-vis NIR Spectrometer. It was found to be as 1.395eV and 1.95eV in Pure CuO and Cr doped CuO thin films.

KEYWORDS: Sputtering Conditions, Copper Oxide Thin Films, CuO

INTRODUCTION

Thin films of CuO have wide range of applications in the gas sensors, solar energy converting devices, TCOs and electro-chromic devices [1] etc. CuO is an attractive material because of several reasons such as natural abundance of starting material copper; the easiness of production by copper oxidation; their non-toxic nature and reasonably good electrical and optical properties. CuO is also a promising material as a selective solar absorber since it has high solar absorbency and low thermal emittance [2].

Various methods to enhance the gas sensing characteristics such as sensing response and selectivity have been reported for n –type semiconductors. However, the gas sensing properties of p-type oxide semiconductors have been extensively studied with out additives (dopants).

Several methods for synthesis of Cr doped CuO thin films have been recently reported in literature such as CVD [3], MOCVD [4,5], MBE [6], PLD [7], thermal evaporation [8] and Sol-gel technique [10]. The dc magnetron sputtering is most suitable technique for the metallic thin films with some interesting advantages when compared to the remaining above methods. In this contrast, Cr doped CuO thin films were prepared by reactive dc Magnetron sputtering at room temperature.

EXPERIMENTAL DETAILS

The Cr doped and undoped CuO films at Room temperature were deposited onto well cleaned Glass substrates (75mm X 25mm X 1mm) by reactive dc Magnetron Sputtering System Developed by VR Technologies, Bangalore. Pure Cr (99.99%) and Cu (99.99%) imported from China were used as the sputtering targets of 2 inch diameter and 3-4 mm thickness. High purity Argon (99.999%) and Oxygen (99.99%) gases were used as the sputtering gas and reactive gas respectively. The target to substrate distance was 50mm. The substrates were cleaned initially by soap water and dried then dipped into the chromic acid for 24 h, then cleaned with de-ionized water and then cleaned with acetone followed by the

Ultrasonic heating. The chamber was pumped to a base pressure of $8x10^{-6}$ m-bar before deposition. The working pressure is $3\text{-}5x10^{-3}$ m-bar. The chamber pressures were monitored with Pirani-Penning gauge combination. The films were grown in the ambient Ar and Oxygen gases flow of 30sccm and 2sccm respectively which were monitored in the Mass flow controllers imported from Germany. The powers of the targets were maintained at 100W and 4W for Cu and Cr respectively. The deposition time was around 30 minutes for all the samples. The crystal structure of the samples was studied by the XRD analysis where the $CuK_{\alpha 1}$ radiation was used as a source (λ= 0.154056 nm) in the 2θ range 20^o-60^o. Field Emission -Scanning Electron Microscopy (FE-SEM) was used to reveal the uniformity of the films. The optical transmittance and reflectance were recorded using a Hitachi U-3400 UV–visible–near infrared (UV-Vis-NIR) double beam spectrophotometer in the wavelength range of 300–1600 nm. The thicknesses of the deposited films were measures by profilometer which was in the range of 500nm.

RESULTS & DISCUSSIONS

Figure 1 reveals that the XRD plot for thin films of CuO and Cr doped CuO at room temperature on glass substrate. The maximum intensity peaks appeared at 2θ=35.54^o and 38.72^o assigned to (0 0 2) and (1 1 1) planes of Monoclinic phase. From the analysis of XRD plot, the FWHM and grain size are changed from 0.2518 to 0.3188^o and 46.9 nm to 35 nm in Pure and Cr doped CuO thin films. The intensity of the maximum peaks declined by the addition Cr into the CuO films.

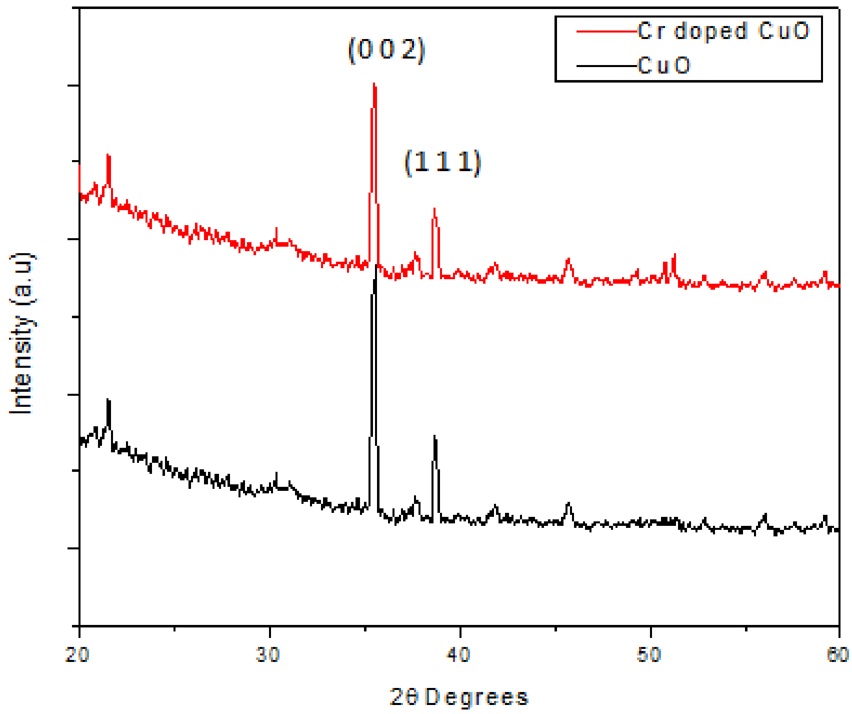


Figure 1: The XRD Results for the CuO and Cr Doped CuO Thin Films at RT

The surface morphologies of the films were studied by FE-SEM which are shown in figure 2. The grains were arranged in uniform manner and the surface of the films were very smooth i.e. the roughness is less. The grain arrangement is clear in Cr doped CuO, pure CuO thin film because of the formation of the compound. The EDAX analysis of the Pure and Cr doped CuO films were shown in figure 3. The compositional analysis reveals that films having all elements i.e. Cr, Cu and O.

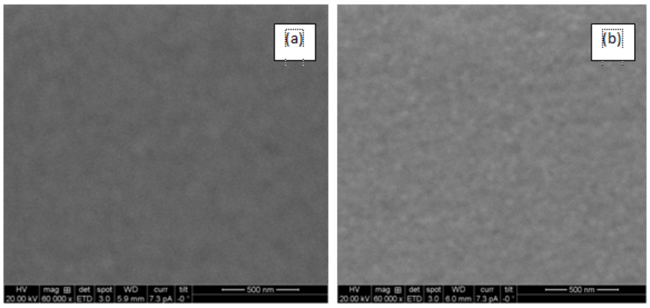
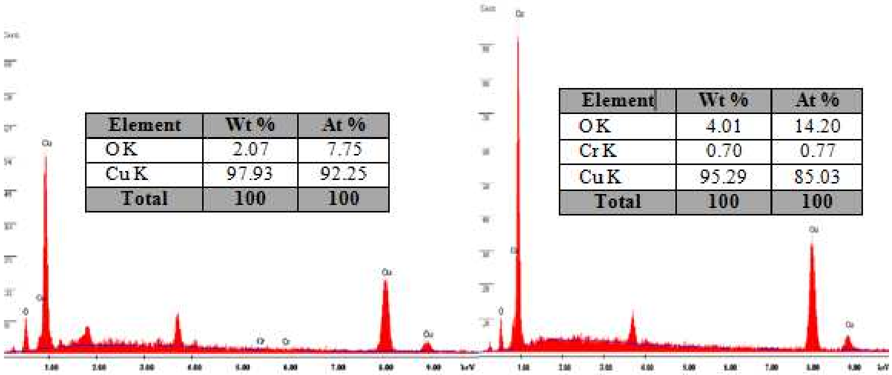


Figure 2



Element	Wt %	At %
OK	2.07	7.75
CuK	97.93	92.25
Total	100	100

Element	Wt %	At %
OK	4.01	14.20
CrK	0.70	0.77
CuK	95.29	85.03
Total	100	100

Figure 3: The FE-SEM and EDAX Analysis of (a) Cu O and (b) Cr Doped Cu O Thin Films

The optical Transmittance and Band gap energies were studied for pure and Cr doped CuO thin films in terms of Optical Studies. The room temperature transmission spectra of pure and Cr doped CuO films in the wavelength range 300-1000 nm are shown in figure 4(a).

It reveals that Pure CuO has low transmittance below 700 nm afterwards it transmits. But in Cr doped CuO the transmittance wavelength range increases and the maximum transmittance was found at 860 nm. For the optical band gap energies, the theory of optical absorption [10] gives the relation between absorption coefficient (α) and photon energy (hυ) as

$$(\alpha h\upsilon)^2 = B(h\upsilon - Eg) \quad (1)$$

Where B ia an energy dependent constant, Eg – Optical band gap.

To calculate the energy band gap, a graph should be plot between $(\alpha h\upsilon)^2$ Vs Photon Energy hυ. By using the graph the energy band gap can be calculated by extrapolating the straight line position in the plot. The Eg values are found as 1.395eV for Pure CuO and 1.95eV for Cr doped CuO thin films. The similar results also reported [11]

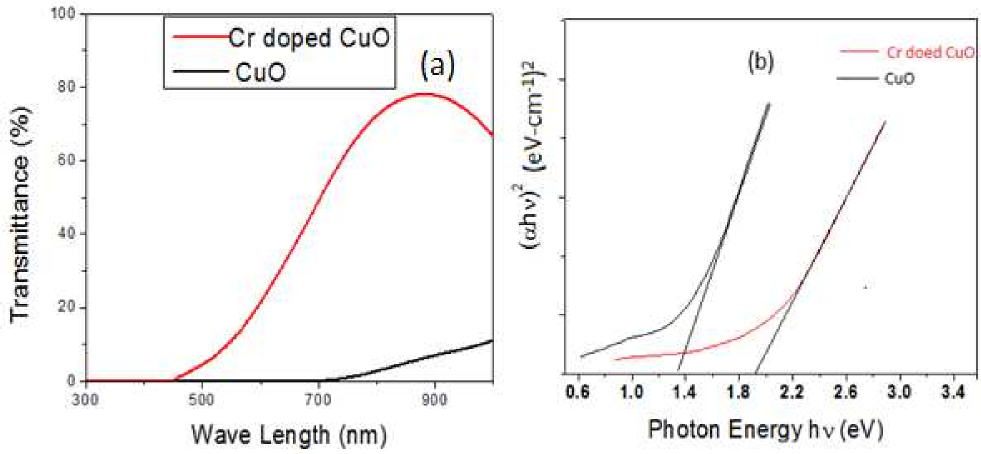


Figure 4: (a) Transmission Spectra and (b) Band Gap Energy for CuO and Cr Doped CuO Thin Films

CONCLUSIONS

Pure and Cr doped CuO thin films were synthesized by dc magnetron sputtering on glass substrate at room temperature successfully. The XRD results show that the films are polycrystalline nature with monoclinic structure. The FWHM of the films were increased with the doping as grin size decreases. The FE-SEM morphology studies show that the deposited films were smooth and uniform in nature. The EDAX analysis show that the Cr doping changes the grains distribution and also confirms that all the elemental compositions present in the films. The optical studies show that the Cr doping in the Pure CuO films enhances the Transmittance and optical band gap.

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